

# LAMOST Quasar Survey

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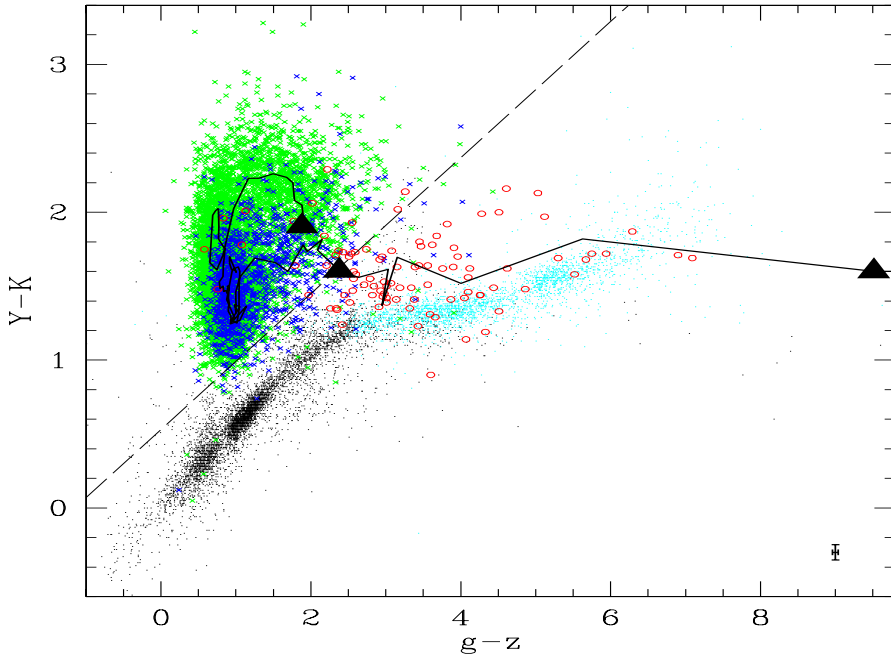
**Abstract.** The main objective of the Chinese LAMOST spectroscopic quasar survey is to discover 0.4 million new quasars from 1 million quasar candidates brighter than the magnitude limit  $i = 20.5$  in the next 5 years. This will hopefully provide the largest quasar sample for the further studies of AGN physics and cosmology. The improved quasar selection criteria based on the UKIDSS near-IR and SDSS optical colors are presented, and their advantages in uncovering the missing quasars in the 'quasar redshift desert' are demonstrated. In addition, some recent discoveries of new quasars during the LAMOST commissioning phase are presented.

## 1. Introduction

Quasars are interesting objects in the universe since they can be used as important tools to probe the accretion power around supermassive black holes, the intergalactic medium, the large scale structure and the cosmic reionization. The number of quasars has increased steadily in the past four decades[1]. Especially, a large number of quasars have been discovered in two recent spectroscopical surveys, namely, the Two-Degree Fields (2DF) survey[2] and Sloan Digital Sky Survey (SDSS) [3]. 2DF mainly selected lower redshift ( $z < 2.2$ ) quasars with UV-excess [4], while SDSS adopted a multi-band optical color selection method for quasars mainly by excluding the point sources in the stellar locus of the color-color diagrams[5]. The efficiency of identifying quasars with redshift between 2.2 and 3 is low in SDSS [6], because quasars with such redshift usually have similar optical colors as stars and are thus mostly excluded by the SDSS quasar candidate selection algorithm. Therefore, the quasar sample of SDSS is incomplete, and the redshift range from 2.2 to 3 is also regarded as the 'redshift desert' of quasars because of the difficulty in identifying quasars within this redshift range.

The Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST) is a 4-meter class reflecting Schmidt telescope with 20 square degree field of view (FOV) and 4000 fibres[7]. It is located at the Xinglong Station of National Astronomical Observatories of Chinese Academy of Sciences. After finishing its main construction in 2008, LAMOST has entered the commissioning phase since 2009. Some test observations have been done in 2009 and 2010. Although LAMOST has not reach its full ability in the commissioning phase, these observations already lead to the discovery of some new quasars[8][9][10]. The main objectives of the LAMOST quasar survey is to discover 0.4 million new

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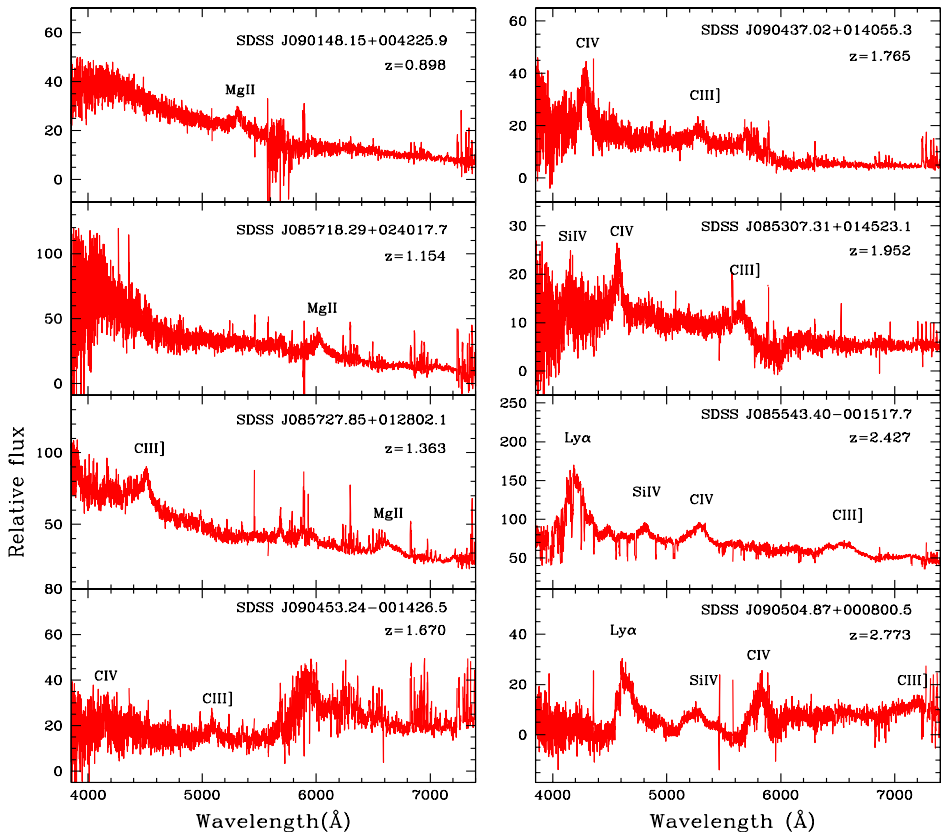


**Figure 1.** The  $Y-K$  vs.  $g-z$  color-color diagram of the SDSS- UKIDSS quasar and star samples. Black and cyan dots represent stars, while green, blue and red crosses represent quasars with  $z < 2.2$ ,  $2.2 < z < 4$  and  $z > 4$  respectively. Dashed line indicates the quasar selection criterion. Solid curve is derived from the median color- $z$  relation of quasars (see [11]).

quasars at magnitude limit  $i = 20.5$  from 1 million quasar candidates selected with the improved selection criteria in the next 5 years. This will hopefully provide the largest quasar sample for the further studies of AGN physics and cosmology in the near future.

## 2. Quasar candidate selection

Although quasars in the 'redshift desert' ( $2.2 < z < 3$ ) have similar optical colors as stars, they are usually more luminous than normal stars in the infrared K-band [13]. An important way of finding these missing quasars has been suggested by using the infrared K-band excess based on the UKIRT (UK Infrared Telescope) Infrared Deep Sky Survey (UKIDSS) [13] [14] [15]. Recently, based on a SDSS-UKIDSS sample of 8498 quasars, Wu & Jia proposed to use  $Y - K$  vs.  $g - z$  diagram to select  $z < 4$  quasars and use  $J - K$  vs.  $i - Y$  diagram to select  $z < 5$  quasars [11]. In Fig. 1 we show the  $Y - K$  vs.  $g - z$  diagram of SDSS-UKIDSS quasar and stars, as well as the proposed quasar selection criterion [11],  $Y - K > 0.46(g - z) + 0.53$  (when  $g, z, Y, K$  are all in Vega magnitude) or  $Y - K > 0.46(g - z) + 0.82$  (when  $g, z$  are in AB magnitude and  $Y, K$  are in Vega magnitude). Recent spectroscopic observations made by us [9][10][12] have demonstrated the high success rate in identifying  $2.2 < z < 3$



**Figure 2.** Spectra of eight new quasars discovered by LAMOST in one shot (see [10]).

quasars from the quasar candidates selected by these new quasar selection criteria, especially when the variability information is combined. Beside using the SDSS-UKIDSS selection method, we also included some quasar candidates from other catalogs[1][16], as well as the additional candidates selected from the SVM method by the NAOC team [17] for preparing the targets of the LAMOST quasar survey.

### 3. New quasars discovered by LAMOST

LAMOST entered its commissioning phase in 2009. In the winter of 2009, we have selected several extragalactic fields for the LAMOST commissioning observations. On December 18, LAMOST made the spectroscopic observations on one field centered at RA=08<sup>h</sup>58<sup>m</sup>08.2<sup>s</sup>, Dec=01°32′29.7″ with the exposure time of 30 minutes and the spectral resolution of  $R \sim 1000$ . Eight new quasars are discovered ([9][10]; See Fig. 2 for their LAMOST spectra). We noticed that two of eight new quasars have redshifts larger than 2.2. These quasars in the ‘redshift desert’ are very difficult to be identified because of their similar optical colors as stars. However, they can be recovered by using the combination of

optical and near-IR colors. Although LAMOST met some problems during the commissioning observations, we were still able to identify many other known SDSS quasars in this field, with  $i$  magnitudes from 16.24 to 19.10 and redshifts from 0.297 to 4.512. The discovery of new quasars supports the idea that by combining the UKIDSS near-IR colors with the SDSS optical colors we are able to efficiently recover the missing quasars in the SDSS spectroscopic survey even at the magnitude limit  $i < 19.1$ .

#### 4. Discussion

A complete quasar sample is very important to the construction of the quasar luminosity function and study the cosmological evolution of quasars. However, because  $2.2 < z < 3$  quasars have similar optical colors as normal stars, it is very difficult to find them in the optical quasar surveys. The low efficiency of finding quasars in the redshift desert ( $z$  from 2.2 to 3) has led to obvious incompleteness of SDSS quasar sample in this redshift range and serious problems in constructing the luminosity function for quasars around the redshift peak (between 2 and 3) of quasar activity [18][19]. Therefore, recovering these missing quasars with the improved quasar selection criteria will become an important task in the future quasar surveys. We hope that great progress will be made in improving the capability of LAMOST spectroscopy before its normal sky survey in 2012. As long as LAMOST can reach its designed capability after the commissioning phase, we expect to obtain 0.4million quasars from 1million candidates in the LAMOST quasar survey in the next 5 years. This will form the largest quasar sample and will undoubtedly play a leading role in the future quasar study.

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